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Author(s):	Elmblad, Joey B
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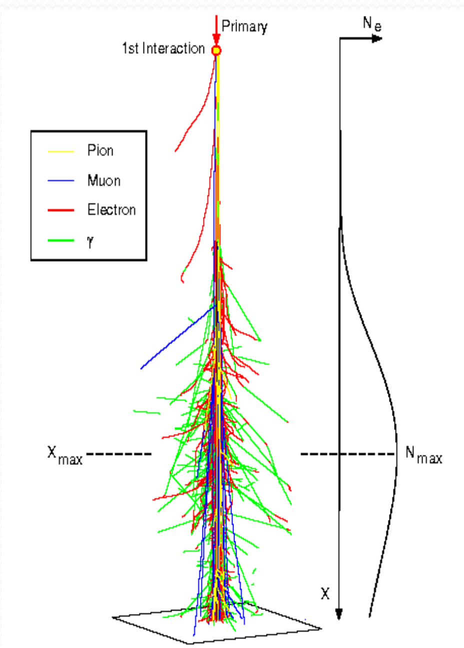
Muon Tomography

Joey B. Elmblad, UNM

Introduction

The muon, being a unstable subatomic particle with a mass 200 times greater then an electron, was discovered by Carl D. Anderswon and Seth Neddermeyer in 1936 researching cosmic rays. These cosmic ray muons were first used by E.P Gerorge in 1955 to measure the depth of the overburden for a tunnel in Australia. Later Luis Alvarez used cosmic ray muons to attempt finding secret passages within the second Pyramid of Giza in 1970. The reason muons penetrate deep within materials is because they are not as sharply accelerated when they encounter electromagnetic fields, and do not emit as much bremsstrahlung. Bremsstrahlung is the electromagnetic radiation produced by the deceleration of a charged particle after passing through the electric and magnetic fields of a nucleus. Using the muon trajectory information accumulated from the MMT (Mini Muon Tracker) we can generate an almost real time representation of the objects in the form of a GUI. The project of researching muon tomography to specifically find security threats had started after the 911 attacks. Muon tomography technology was demonstrated in Japan to potentially assist in the cleanup of the Fukushima reactor meltdown. Potentially the clean-up will be finished sooner and unnecessary doses of ration will be avoided. Currently the Threat Reduction Team is constructing a super module made with carbon fiber, which will be carried by hand and result in better muon tomography resolution.

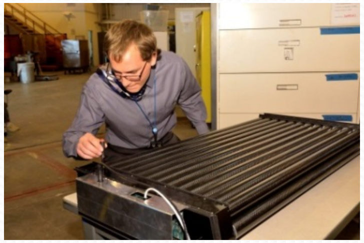
Figure 1: Example of primary cosmic rays striking our upper atmosphere.



Prototype

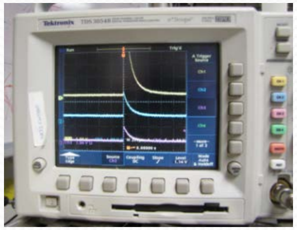
The density of carbon fiber is 1.55 g/cm^3 compared to the aluminum of 2.7 g/cm^3. Our newer carbon fiber super modules will approximately weight 250lb compared to the 760lb Aluminum super modules. These super modules weight differences are proportional to their densities. The higher density of material increases the probability of muons scattering. When the material for the super module is made of dense material it is expected to have a lower quality of resolution. Therefore, a less dense material such as carbon fiber will enhance the resolution and weigh less.

Figure 2: Picture of a single carbon fiber module.



I performed initial calibration testing and analysis on the 24 individual drift tubes from each module. Each module has a board with pins to access each of these tubes individually, 12 of these modules makes a super module. The drift tubes have a 50% Ar, 44% CF_4, 6% C_2H_6 gas concentration combination with a tungsten gold plated wire running down each. The microscopically smaller gases are used to be ionized and the larger ones as quencher gases to prevent discharges. High voltage powers up the tungsten gold plated wire, which picks up and amplifies the charge from the muons activating the gas within each drift tube. Each drift tube should produce a 20-30mV voltage peak. To find an efficient level of voltage for the super module I constructed a handmade lemo cable to connect with a module, which can collect data from three drift tubes at once. The module you seen above will be placed on its side to have muons cross three drift tubes in a line. When the top drift tube and the bottom drift tube both track the same muon it can be compared to the middle drift tube to produce an efficiency of that middle drift tube. The efficiency of the middle drift tube will be tested at different levels of power to find which voltage generates the best results.

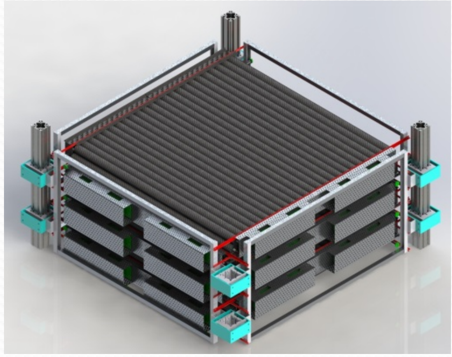
Figure 3: Coincidence showing a single muon hitting three drift tubes.



Application to real world situations

With the weight reduction of the carbon fiber super module it can now potentially be used to scan for nuclear weapons or shielding in multiple different situations. The weight of this super module will be approximately 250lb which can be moved by hand. In the application for scanning buildings the carbon fiber MMT, consisting of 2 super modules, can be moved by hand to different locations. This would be more ideal for areas of interest instead of scanning the whole building. By placing the carbon fiber super module horizontally, it can scan cargo containers, boats, airplanes, and vehicles. However having the super module on its side will delay the scan because the muons are mostly hitting the earth in a vertical projection rather than horizontal. Homeland Security for Exploratory Research in Preventing Nuclear and Radiological Terrorism are willing to fund five different categories of exploratory research topics that can be used to protect our borders. One of these categories includes Shielding Anomaly Detection of vehicles, cargo containers, boats, airplanes, or buildings. The length and height of the modules for the carbon fiber MMT can be modified for anyone of these situations included in the Shielding Anomaly Detection section for Homeland Security for Exploratory Research in Preventing Nuclear and Radiological Terrorism. The world will become a safer place with these detectors placed on borders to scan for nuclear materials that otherwise could pass undetected.

Figure 4: Solidworks figure of a carbon fiber super module.



Team: Chris Morris, Jeffery Bacon, Matthew Durham, Joey Elmblad, Joseph Fabritius, Shelby Fellows, Elena Guardincerri, John Perry, Kenie Plaud, Daniel Poulson, Zhehui Wang